

[fol. 448]

3. *The CBS System*

94. At all of the demonstrations on the record, the CBS picture compared favorably with the present system so far as contrast, sharpness of picture, and freedom from line structure are concerned. As above stated, the geometrical resolution of the CBS picture was inferior to a picture under the present standards.

95. During the course of the hearing there was a good deal of discussion concerning "crispening" in the CBS system, whereby apparent definition is improved by making the picture appear sharper. Crispening circuits do have the capacity of producing sharper pictures. While their use may not be limited to any one system, no demonstration of crispening was had with any of the other systems, and, accordingly, it is not possible to determine what the extent of improvement for these systems would be. Moreover, it is doubtful whether crispening can be utilized by a system employing horizontal interlace.

96. If horizontal interlace were utilized on the CBS system, the picture texture could be affected thereby. Dot structure or twinkle could appear in the picture. CBS testified that this could be avoided in its system utilizing horizontal interlace. Satisfactory proof of this point requires further testing.

4. *The RCA System*

97. The RCA picture has a "soft" quality when compared to pictures of the present system. This is probably due to the difficulty in maintaining contrast, particularly in small areas. Picture texture was also marred at all of the demonstrations on the record by the visibility of dot structure at distances at which the lines begin to be unresolved. RCA testified that the dot structure could be minimized by the use of electrical filters, but no demonstration of this process was made on the record. Moreover, it appears to the Commission that if the dots are smoothed out, the consequences are likely to be a loss in resolution or contrast, or in both.

[fol. 149]. H. *Susceptibility to Interference*1. *General*

98. The quality of a television picture can be marred not only by inherent defects but also by interference. The sources of interference include not only television signals from other stations on the same or adjacent channel but also ignition systems, diathermy, oscillator radiations from other receivers, etc. So far as co-channel interference is concerned, a process known as offset-carrier operation gives promise of reducing the effects of interference. The process will be fully explored in subsequent phases of this hearing but enough evidence was introduced on the subject in the color phase of the hearing to warrant consideration so far as susceptibility of the three systems to interference is concerned.

2. *The CTI System*

99. In general, the CTI system appears to have the same susceptibility to interference as the present system. However, no evidence was introduced concerning offset-carrier operation on this system. There is some reason to believe that the CTI system would not derive as much benefit from offset-carrier operation as would black and white television or the other two color systems because there is likely to be a coarse beat between system line structure and offset line structure.

3. *The CBS System*

100. The CBS system has about the same susceptibility to interference as the present system for both normal operation and offset-carrier operation. If horizontal interlace is utilized, the system may be susceptible to oscillator radiation and other forms of continuous wave interference. CBS testified that its system with horizontal interlace would not be susceptible to this type of interference but had no demonstration which proved the point. The Commission believes that further testing is necessary before the CBS contention can be accepted.

4. *The RCA System*

101. With the exception noted below, the RCA system has about the same susceptibility to interference as does the present system, both for normal operation and offset-carrier operation. The exception is in the case of oscilla-

tor radiation and other forms of continuous wave interference where a greater susceptibility to interference exists than for the present system or the other two color systems. This is caused by the presence of the sampler synchronizing pulse and the color subcarrier which are not present in the black and white system or the other two color systems. A demonstration of oscillator radiation such as would be received from other television receivers not only caused severe interference to the picture but under certain conditions upset color synchronization so that color control was lost.

[fol. 150] I. *Adaptability and Convertibility*

1. *General*

102. The Commission's Notice of Further Proposed Rule Making in these proceedings provided that proposals for changes in transmission standards so as to provide for color television would be considered only if a showing were made, *inter alia*, that:

"Existing television receivers designed to receive television programs transmitted in accordance with present transmission standards will be able to receive television programs transmitted in accordance with the proposed new standards simply by making relatively minor modifications in such existing receivers."

It is not entirely clear from a reading of the language itself as to whether the above requirement is directed to the changes in existing receivers necessary to enable them to receive color programs in black and white, or in color, or in both. However, it does appear to be clear from a reading of the above provision in the context of the entire notice that it covered both requirements. In a proceeding involving a possible change of standards where several million receivers were already in the hands of the public it was obviously important to ascertain the changes that would be required to enable existing black and white receivers to continue receiving pictures in black and white and also the changes necessary to enable them to receive the new color pictures in color. The parties themselves must have construed the notice in the same way since they addressed themselves to both facets of the problem.

103. At the hearing, some dispute developed concerning the appropriate words to be utilized in describing each facet of the problem. In order that there should be no ambiguity as to the meaning of the words as utilized in this Report, the word "adaptability" will be utilized to cover the changes that are required to enable existing receivers to receive a black and white picture from color transmissions, and the word "convertibility" will be utilized to cover the changes that are necessary to enable existing receivers to receive color transmissions in color. The word "compatibility" covers the specialized case of adaptability where no change whatsoever is required in existing receivers in order to enable them to receive a black and white picture. No correlative term is employed so far as convertibility is concerned since no system was proposed where existing receivers without making any changes whatsoever could receive color transmissions in color.

[fol. 151]

2. *The CTI System*

104. No change whatsoever is required in existing receivers in order to enable them to receive a black and white picture from CTI color transmissions. However, the picture so received is substantially inferior in quality to a regular black and white picture. This is due to the prominent line structure, jitter, and line crawl which are present in the CTI system. As to convertibility, CTI does not contend that as a practical matter existing receivers can be converted to receive color transmissions in color.

3. *The CBS System*

105. Existing receivers are unable to receive a black and white picture from CBS color transmissions without making some changes in the receivers to enable them to handle the different vertical and horizontal scanning rates. These changes may be made either by rewiring the circuits, or by attaching an external adapter. CBS presented evidence from manufacturers experienced in the field indicating that the retail price of external adapters, exclusive of installation charges, would range from \$32 to \$50, and that adaptation may be accomplished by rewiring the circuits at a somewhat lower price; automatic switching from 525-line monochrome to 405-line CBS transmissions could be

effected at an additional cost of about \$5 to \$15.²⁶ Testimony was also introduced concerning the adaptation by the Commission's laboratory of four conventional 7-inch and 10-inch receivers. Parts for the conversions—at a cost level somewhere between retail prices and manufacturer's prices—ranged from about \$4 to \$12, the higher figure including automatic switching; labor and installation costs would be extra. Philco gave a list price of \$45 to \$50 for an external adapter, with other changes in the receiver and various unitemized costs bringing the total cost to between \$75 and \$100; and DuMont estimated the total cost to be between \$100 and \$125. The Philco and DuMont estimates appear to be unreasonably high in the light of the cost of the parts required for adaptation, and seem to have been based on the replacement of major parts rather than on the minimum necessary changes.²⁷

106. Existing receivers can be converted to enable them to receive CBS color transmissions in color by the addition of an adapter to change the scanning rates and a rotating color filter disc; a magnifying lens may also be added to increase the picture size. Based upon evidence offered by independent manufacturers called as CBS witnesses, the retail price of adapting and converting an existing 7-inch tube receiver to CBS color to provide a 10-inch picture (magnified) would range from \$95 to \$130. Likewise, a 10-inch tube set could be adapted and converted to provide a 12½-inch picture (magnified) for from \$110 to \$150, and a 12½-inch set to provide a 16-inch picture (magnified) for from \$125 to \$170. Since the rotating disc must be [fol. 152] placed in front of the cathode-ray tube, some existing receivers with doors or recessed tubes would, in practice, be difficult to convert. As will be explained in Paragraph 111, on receivers with direct view tubes larger

²⁶ The figures quoted in this paragraph refer to external adaptation for existing receivers. The cost of building the necessary additional circuits into a new receiver at the factory to permit it to receive CBS transmissions is substantially lower.

²⁷ For example, the DuMont estimate included the following items: Sweep conversion unit, \$80, different yoke and transformer, \$15, and service charge, transportation, etc., \$25. Philco did not supply a similar cost breakdown as applied to its estimates.

than 12½ inches, the color pictures will be reduced to 12½ inches unmagnified or up to 16 inches magnified. Philco and DuMont indicated that the cost of conversion would be much higher than indicated above but the Commission is unable to accept their estimates for the reasons set forth in the preceding paragraph.

4. *The RCA System*

107. No change whatsoever is required in existing receivers in order to enable them to receive a black and white picture from RCA color transmissions. However, the picture so received is somewhat inferior to present black and white pictures which may be due to the appearance of dots in the picture and to misregistration at the camera. So far as convertibility is concerned, no practical converter was demonstrated at any of the demonstrations on the record.

J. *Equipment Considerations*

1. *The CTI System*

108. At the present time, apparatus in the CTI system is limited to projection receivers. In black and white television, projection receivers have not had widespread acceptability in the market. The CTI receiver is bound to be more complex than present receivers principally because of the difficulty of maintaining image registration. The control for this purpose is very critical and in its present stage is beyond the capabilities of the average viewer under normal home viewing conditions, as is evident from the fact that even trained technicians were unable to maintain accurate registration throughout any one of the demonstrations that were held on the record.

109. At the station, no change is required in the transmitter or antenna to broadcast CTI color. Extensive changes are required in the camera and associated studio equipment. Based upon CTI's estimates the cost of converting a single existing studio camera chain is about \$7,000. Moreover, this equipment is likely to be quite complex since very critical tolerances must be achieved and maintained if registration is to be accurate. This means complex and expensive equipment to begin with; costly maintenance work to keep the critical parts of the equipment in perfect operating condition; and frequent re-

placement of expensive tubes when they start to deteriorate at an uneven rate. These difficulties are the ones that will be encountered in studio equipment. So far as equipment for outdoor pickups is concerned, none was demonstrated by CTI. The difficulties here are even more pronounced than for studio equipment since such equipment must be capable of being moved about from one spot to another and it is subjected to varying conditions.

[fol. 153] 110. So far as networking is concerned, no special problems are presented. The present inter-city facilities of common carriers are either radio relays which are capable of a 4-megacycle response or coaxial cables which are capable of a 2.7 megacycle response. CTI color programs can pass over either type of facility. Of course, a CTI color program which is transmitted over a 2.7 megacycle cable suffers a reduction in horizontal resolution in the same way as does a black and white picture.

2. *The CBS System*

111. At the present time, the apparatus in the CBS system is limited to projection receivers or to color pictures (unmagnified) of approximately $12\frac{1}{2}$ inches on a direct view tube in a disc type receiver. The limitation on direct view tubes in disc receivers arises from the fact that the diameter of the disc must be at least twice that of the tube. It is not practical to have a disc much larger than 26 inches in diameter in the home. Receivers can be made with tubes larger than $12\frac{1}{2}$ inches and the full surface of the tube can be utilized to view black and white pictures; the disc folds aside when black and white pictures are being received. For such larger tubes, the picture must be reduced to no more than $12\frac{1}{2}$ inches when a color picture is being viewed. Of course, the viewer may, if he chooses, utilize a magnifying lens to increase the $12\frac{1}{2}$ inch picture to 16 inches. Magnifying lenses have not been popular in black and white receivers since they severely restrict the viewing angle and are susceptible to annoying specular reflections from lights in the room. According to testimony of manufacturers called as CBS witnesses, new combination black-and-white and CBS disc-type color receivers could be sold at a retail price of approximately \$200 for a 7-inch tube magnified to 10 inches, and approximately \$300 for a 10-inch tube magnified to $12\frac{1}{2}$ inches. DuMont testified that a new combination black-and-white and CBS disc receiver, using

a 12-inch tube (without magnification) could sell for \$500 to \$600 based on an annual production of 100,000, compared to \$329 for a DuMont black-and-white set of similar quality.²⁸

112. The operation of the CBS disc type receiver is relatively simple. Since CBS proposes that the present monochrome standards be retained for black and white pictures, a manual or automatic switch is necessary to handle the monochrome standards for black and white pictures and the CBS standards for color pictures. When the viewer desires to tune in a color program, he turns a switch which operates the adapter and also turns on the motor which turns the disc. As soon as the motor reaches full running speed, the viewer presses a button that is designed to make sure that the particular color filter in front of his tube is [fol. 154] the same color as the one before the camera; this can be done by inspection. One or two pushes of the button are necessary for this purpose.²⁹ When this is done, nothing further need be done. As can be seen, color control is quite simple and it is not at all critical. The color switching is accomplished at the relatively slow rate of 144 times per second, and hence receivers for the CBS system are relatively simple. Since two different standards of transmission are provided under the CBS proposal for black and white and color, it is apparent that broadcasters cannot readily change from color to black and white or vice versa

²⁸ RMA Exhibit 408, entitled "Time Availability and Cost of Apparatus Necessary for Color Television," consists of replies by various manufacturers to a letter from Dr. W. R. G. Baker, Director of RMA Engineering Department, which he sent to all 54 members of the RMA Set Division. Dr. Baker testified that "I didn't recommend that they (the Commission) give serious consideration to this exhibit, if I remember rightly. I said this was a very rough approximation and I explained in detail why." The Commission has not given this exhibit serious consideration not only because of Dr. Baker's statement, but also because no supporting data were submitted with respect to the above cost estimates, and most of the manufacturers submitting estimates did not appear to testify concerning them and were not available for cross-examination.

²⁹ See Paragraph 44 for reference to automatic color phasing shown at the Laurel demonstration.

(e.g. a black and white program with color commercials) during the course of a program.

113. At the station, no change is required in the transmitter or antenna. The camera and associated equipment do require changes and CBS submitted evidence that an existing studio camera could be converted for \$3,622 and that CBS had brought a new color camera chain from RCA for approximately \$27,000. The use of the disc in the camera presents no problem since camera tubes are relatively small in diameter. The color controls in the CBS camera are not critical and CBS successfully demonstrated on the record outdoor pickups as well as studio performances.

114. So far as networking is concerned, CBS color pictures can be transmitted over the radio relay or coaxial cable. The coaxial cable reduces the horizontal resolution in the same manner as black and white pictures.

3. *The RCA System*

115. At none of the demonstrations on the record was a practical RCA home receiver shown. The projection receivers shown at the first demonstration were withdrawn by RCA and not resubmitted. The direct view receiver consisting of dichroic mirrors and three kinescopes is so bulky, so complex, and so expensive that it could not be seriously considered for home use. The controls are so critical that even trained technicians were unable to maintain correct registration and color fidelity throughout a single demonstration on the record.

116. RCA showed a tri-color tube at the demonstration on the record held April 6, 1950. Even at that demonstration, there was evidence of faulty registration, although it does not appear whether such misregistration was due to the receiver or camera, or both. Since color control is extremely critical in the RCA system, there can be no assurance that the fault does not exist at both ends. Moreover, there is no assurance on the record that the tube is an assured fact.³⁰ The tube was demonstrated towards the

³⁰ RCA testified that within 60 to 90 days from May, 1950, it expected to have developmental model color receivers using the tri-color tube available for field tests; during

[fol. 155] close of the hearing and has had very little field testing. It has not been made available to other parties or to the Commission's laboratory for study. An RCA witness testified that the tube would cost about 50 to 100 percent more than black and white tubes of similar size at the same relative stage of development; no data were submitted in support of this estimate. Finally, as demonstrated, the tube developed insufficient illumination, it had an inadequate number of dots, and it had a serious moire pattern in it.

117. In any even, RCA color receivers are expected to be more complex than receivers of the other two systems. Since a time error of only $1/11,000,000$ of a second adversely affects color fidelity (see Paragraph 87), many of the components must be built to a very critical tolerance. Moreover, since RCA utilizes a subcarrier of 3.6 megacycles for the purpose of carrying its color information, receivers must be built with a band pass of at least 3.6 megacycles. Many of the cheaper receivers today are built with a band pass narrower than 3.6 megacycles. Early in the proceedings RCA demonstrated projection and direct view color receivers. An RCA witness testified that a 10-inch direct view three tube set would cost between \$650 and \$800; a 7-inch by $9\frac{1}{2}$ -inch projection receiver would cost between \$550 and \$700; a 15-inch by 20-inch projection receiver would cost between \$800 and \$1000; and a two color direct-view 10-inch receiver would cost between \$400 and \$550. As was indicated above, the projection receivers and two-color receivers shown at the first demonstration were not demonstrated again by RCA. With respect to receivers containing a tri-color tube, an RCA witness testified that the set itself aside from the tube was likely to be between 25 to 50 percent more expensive than a black-and-white receiver of the same size and character, and that the tube itself was likely to be between 50 and 100 percent more expensive than black and white tubes of similar size.

118. At the station no change is required in the transmitter or antenna. Extensive changes are required in the

September, 1950 5 or 6 such receivers would be produced each week from a pilot assembly operation. Factory production at a weekly rate of 200 receivers would begin by June, 1951 if RCA standards were adopted, and by the end of 1951, the rate would be 1000 per week.

camera and associated equipment. RCA admitted that existing camera equipment cannot be converted. It estimated that the cost for new RCA color studio camera equipment would be \$54,440. This would include one camera chain, the necessary 3-image orthicons, a pedestal, a friction head, a flag burst generator, crystal standard, power supply and cabinet rack, a color monitor, and power supplies for the monitor. An additional color camera would cost \$26,750. Moreover, the equipment is likely to be very complex since extremely critical tolerances must be achieved and maintained. This means complex and expensive equipment to begin with. It also means costly maintenance work to keep the critical parts of the equipment in precise operating condition and frequent replacement of expensive tubes when they start to deteriorate at an uneven rate. The difficulties are compounded so far as outdoor pickup is concerned, which RCA did not demonstrate on the record. Outdoor equipment must be capable of being moved around from spot to spot and is subjected to varying conditions.

119. So far as networking is concerned, radio relays have a response to 4 megacycles and would handle RCA color transmissions. The coaxial cable has a response of 2.7 megacycles and, accordingly, RCA color transmissions come through the coaxial cable as black and white pictures with reduced horizontal resolution. At the April 6, 1950 demonstration on the record, RCA simulated a color transmission over the coaxial cable by utilizing a frequency limiting circuit. To accomplish this, the signal was originally sampled at a 3.6 megacycle rate and then before going into the circuit that simulated the cable, it was resampled at a 2.4 megacycle rate. When it comes off the cable, it is again resampled at the 3.6 megacycle rate. In the demonstration, a color picture was received, with reduced horizontal resolution. This process would require extra terminal equipment on the cable not required for CTI or CBS color transmissions. Further testing on the cable itself is required before a final judgment can be made.

[fol. 157]

IV. CONCLUSIONS

A. General

120. The testimony and demonstrations in these proceedings leave no room for doubt that color is an important

improvement in television broadcasting. It adds both apparent definition and realism in pictures. It opens up whole new fields for effective broadcasting, rendering life-like and exciting scenes where color is of the essence—scenes which in black and white television are avoided or, if telecast, have little appeal.

121. Because color is such a fundamental improvement in television, the Commission is of the opinion that in establishing standards, a system must be chosen that produces a satisfactory color picture and is capable of operating through apparatus that is simple to operate in the home and is cheap enough in price so as to be economically available to the great mass of the American purchasing public. The Commission is of the firm opinion that it would not be in the public interest to establish a television system where only black and white receivers are cheap enough for the great mass of the American people and color television is available to those who can afford to pay luxury prices.

122. In order for a color system to be considered eligible for adoption, it must meet the following minimum criteria:

a. It must be capable of operating within a 6-megacycle channel allocation structure.

b. It must be capable of producing a color picture which has a high quality of color fidelity, has adequate apparent definition, has good picture texture, and is not marred by such defects as misregistration, line crawl, jitter or unduly prominent dot or other structure.

c. The color picture must be sufficiently bright so as to permit an adequate contrast range and so as to be capable of being viewed under normal home conditions without objectionable flicker.

d. It must be capable of operating through receiver apparatus that is simple to operate in the home, does not have critical registration or color controls, and is cheap enough in price to be available to the great mass of the American purchasing public.

e. It must be capable of operating through apparatus at the station that is technically within the competence of the type of trained personnel hired by a station owner who does not have an extensive research or engineering staff at his disposal and the costs of

purchase, operation, and maintenance of such equipment must not be so high as unduly to restrict the class of persons who can afford to operate a television station.

[fol. 158] f. It must not be unduly susceptible to interference as compared with the present monochrome system.

g. It must be capable of transmitting color programs over inter-city relay facilities presently in existence or which may be developed in the foreseeable future.

123. It should be noted that the above criteria do not include compatibility. The Commission is of the opinion that if a satisfactory compatible system were available, it would certainly be desirable to adopt such a system. Compatibility would facilitate for the broadcaster the transition from black and white broadcasting to color broadcasting and would reduce to a minimum the obsolescence problem of present receivers. However, as will be developed more fully later on in this Report, no satisfactory compatible system was demonstrated in these proceedings and the Commission is of the opinion, based upon a study of the history of color development over the past ten years, that from a technical point of view compatibility, as represented by all color television systems which have been demonstrated to date, is too high a price to put on color. In order to make these systems compatible, the alternatives have been either an unsatisfactory system from the standpoint of picture quality, or a complex system, or both. A complex color system will have such formidable obstacles in its path that there is no assurance it would be acceptable to the American public. The Commission is compelled to reach the conclusion that no satisfactory compatible color system has been developed.

124. The receiver aspect of compatibility, moreover, is merely a temporary problem which will decrease progressively each year once receivers are built incorporating new standards. Based upon an assumption of 7,000,000 sets in the hands of the public at the present time, the problem of compatibility would be diluted each year depending on the annual rate of production. It is not possible to forecast what the annual rate of production would be, but, by way of illustration, if sets were continued to be manufactured at the present rate of production (e.g., five

to six million sets a year) then one year after the adoption of an incompatible system approximately 40% of the receivers in the hands of the public should be capable of receiving these signals without any change whatsoever—they will have been built that way.³¹ The percentage will become progressively larger each year. So far as owners of existing receivers are concerned, if they make no change, they will still be able to receive programs broadcast in accordance with present monochrome standards—there will undoubtedly be such for several years after a decision—or they can spend the relatively minor amount of money necessary to adapt their sets and thus be able to receive all programs in black and white or they can spend a slightly larger amount and get color programs in color. It would not be in the public interest to deprive forty million American families of color television in order to spare the owners of seven million sets the expense required for adaptation.

[fol. 159] 125. The criteria set forth in Paragraph 122 likewise do not include any reference to convertibility or adaptability. Much of the reasoning applicable to compatibility applies likewise to convertibility or adaptability. While there is some doubt as to whether some of the color systems proposed here meet the test of adaptability and convertibility (as defined in Paragraph 103) contained in our Notice of July 11, 1949, no objection was raised by the Commission or any of the parties to the consideration of any of the color systems proposed herein and no objection is raised in any of the Proposed Findings or Replies. Accordingly, the three systems are considered on the merits.

126. During the hearing evidence was introduced to show the patent position which is held by RCA in the television field, and one of the parties urged the Commission to reject the RCA system in order to encourage competition and avoid monopoly. The Commission recognizes that if a monopolistic patent position exists in the radio field, it would tend to discourage fundamental research by other

³¹ The Commission is aware that some manufacturers expressed a reluctance to build sets for an incompatible system if it is approved by the Commission. We believe that an informed public would demand receivers that are capable of getting programs from all television stations in the area and that the manufacturers would build such receivers.

companies and would tend to foster concerted action on the part of the patent licensor and its licensees, which could result in control of receivers sold to the public. However, on the record in these proceedings we do not believe that we are called upon to make a decision as to whether RCA does have a monopolistic position in the radio field, as urged by some, or merely one of leadership, as contended by RCA, because the decision as to whether the RCA system should or should not be adopted is based solely on a consideration of the system on the merits. If the Commission should find that a monopolistic situation does exist or such a situation should develop, appropriate proceedings can be instituted under the anti-trust laws or the Commission can seek from Congress legislation to prevent the building of monopolistic patent structures in the radio field, or both.

B. The CTI System

127. The Commission is of the opinion that the CTI system falls short of the criteria we have established for a color system. In the first place, the quality of the color picture which the CTI system produces is not at all satisfactory. There is a serious line crawl problem and the picture texture is not satisfactory. These defects were clearly evident at the demonstrations on the record at the low levels of illumination there used. With the higher illuminations that would be required for home viewing, the defects would be more pronounced. Improvements in apparatus will in all probability not eliminate these defects since they appear to be inherent in the CTI line sequential system.

[fol. 160] 128. In the second place; there is great doubt as to whether CTI even qualifies on what it claims to be one of its principal advantages—compatibility. There is a serious degradation in quality of the black and white pictures which existing receivers get from CTI color transmissions. While the Commission would not rule out an otherwise satisfactory color system merely because some degradation resulted in the black and white pictures which existing sets would receive from the color transmissions, a serious problem would be presented where the degradation is as substantial as in the case of the CTI system.

129. In the third place, the equipment utilized by the CTI system is unduly complex. At the receiver, image regis-

tration control is so critical that it is entirely unlikely that the average person could successfully operate it. At the station end, the equipment is likewise so complex that even though trained personnel would be available, it is most doubtful that they could maintain the equipment in the precise operating condition that is necessary for the system for a regular broadcast operation. This difficulty will be particularly onerous in the case of outdoor pickup equipment which is subject to much harder use and rougher handling than studio-equipment. CTI did not demonstrate any outdoor pickup equipment.

130. In the fourth place, CTI did not offer sufficient evidence on which a finding could be based as to whether the system is unduly susceptible to interference. While the evidence introduced does indicate that the system has approximately the same susceptibility to interference as the present monochrome system so far as normal operation is concerned, no evidence was offered concerning offset carrier operation and there is reason to believe that the CTI system would not derive as much benefit from offset carrier operation as the present monochrome system or the other two color systems.

131. So far as networking is concerned, CTI color transmissions are capable of being relayed over both coaxial cable and microwave relays.

C. The RCA System

132. The RCA system also falls short of the criteria set forth above. In the first place, the color fidelity of the RCA picture is not satisfactory and it would obviously not be in the public interest to adopt as standard a color system which does not produce a satisfactory color picture. At none of the demonstrations on the record could RCA consistently produce pictures with adequate color fidelity. The inability accurately to reproduce skin tones is a particularly serious handicap. There appears to be no reasonable prospect that these difficulties in the RCA system can be overcome, because of misregistration, mixed highs, cross talk between picture elements, and criticalness of color control implicit in a system where a time error of $1/11,000,000$ of a second results in color contamination.

[fol. 161] 133. In the second place, the texture of the color picture is not satisfactory. At all of the demonstra-

tions the quality of the picture was marred by misregistration and also to a certain extent by dot structure. Indeed, even on the score of compatibility the quality of black and white pictures which existing sets receive from RCA color transmissions is somewhat degraded because of dot structure and misregistration at the camera; however, the black and white picture remains of reasonably good quality. Moreover, the RCA color picture has a "soft" quality, probably due to the difficulty in maintaining contrast, particularly in small areas. It is difficult to see how these defects can be eliminated. Correcting misregistration in the RCA system is an exceedingly difficult task as has already been indicated. Smoothing out the dot structure can mean losing resolution or contrast, or both. Poorness of contrast, particularly in small areas, appears to be the price of mixed highs, cross talk, and dots which are larger than single picture elements.

134. In the third place, the receiving equipment utilized by the RCA system is exceedingly complex. The Commission would certainly not consider adopting a system which was limited to receivers of the dichroic mirror type demonstrated on the record. These receivers are so bulky, so complicated, so difficult to operate, and so expensive that it is inconceivable that the public would purchase them in any quantity. RCA did demonstrate a receiver using a direct view tri-color tube towards the end of the hearing but the Commission is not satisfied that the tube solves the problem of complex receivers. The tube was not demonstrated until late in the proceedings and has had very little field testing. It has not been available to other parties or the Commission's laboratory for the purpose of checking its operation. As demonstrated, the tube had an inadequate number of dots, produced insufficient illumination, and had a serious moire pattern in it. There is no assurance that the tube will not be unduly expensive, for while an RCA witness testified that the tube would cost 50 to 100 percent more than black and white tubes of corresponding size, no data were submitted in support of this estimate. Finally, even though the tube is developed, there is no assurance that the receivers will not continue to be unduly complex and difficult to operate. Since a time error of $1/11,000,000$ of a second results in color contamination, it is difficult to see how color control can be simplified to a sufficient extent for home use.

135. In the fourth place, the equipment utilized at the station is exceedingly complex. There is no assurance that satisfactory commercial type equipment can be built because at not a single demonstration on the record was accurate registration maintained throughout the demonstration. Moreover, there is such great difficulty in maintaining the equipment in the precise operating condition which the system entails that it is extremely unlikely that the job could be done by an organization that does not have an extensive staff of research personnel and engineers at its disposal. The type of trained personnel which is generally available to the average station could hardly be expected to handle such a difficult job. The above difficulties will be particularly onerous in the case of outdoor pickup equipment which is subject to much harder use and rougher handling than studio equipment. RCA did not demonstrate any outdoor pickup equipment.

136. In the fifth place, the RCA color system is much more susceptible to certain kinds of interference than the present monochrome system or the other two color systems. A demonstration of oscillator radiation such as would be received from other television receivers not only caused severe interference to the picture but under certain conditions upset color synchronization so that color control was lost.

137. So far as networking is concerned, RCA color transmissions can be handled by inter-city relays with 4-megacycle capacity but there is not adequate assurance on this record that color pictures can be transmitted over the 2.7 megacycle coaxial cable facilities. On this point, the common carriers who testified at the hearing indicated that they are progressively increasing the percentage of their inter-city facilities which are represented by microwave relays. Moreover, the coaxial cable is capable of being modified to accommodate 4 megacycle television transmissions. The Commission expects the common carriers to have 4 megacycle facilities for all television programs as soon as possible so that the public will not be required to accept network programs which are substantially degraded in horizontal resolution.

138. Finally, the RCA system has not met the requirements of successful field testing. The system introduces entirely new techniques into broadcasting, principally dot sampling and the use of mixed highs. Extensive field test-

ing is required before a final answer can be given as to the value of these techniques. The Commission is still of the same view today as it was in March 1947 when it rejected the former CBS color system—a much simpler system and one which had more field testing than the RCA system. At that time, it stated:

“Before approving a new system of television it is indispensable that there be an adequate program of field testing. Receivers and transmitters must be subject to numerous tests over a long period of time and at a diversified set of locations and operating conditions so that operation under average home conditions is closely approximated. Without such field testing, there is no assurance that all fundamental defects have been eliminated. There is a great difference between the performance of a system in a laboratory with trained personnel and its operation in the home by the average citizen. In the history of electronics there have been developments which looked promising in theory and even in operation in the laboratory but which revealed such fundamental defects when subjected to adequate field testing that they had to be abandoned entirely.”

RCA has not successfully shown that its equipment is simple enough to be operated by the average individual; the testimony of a trained expert that it can be done is not a satisfactory substitute.

139. In ruling out the RCA system, the Commission has not overlooked the testimony of the many radio manufacturers who directly, and through their trade association, endorsed the dot sequential system. The Commission is aware that of necessity it must rely to a great extent upon industry experts for data and expert opinion in arriving at decisions in the field of standards; our own facilities are too limited to gather much of the data. However, the responsibility for decision is that of the Commission and we cannot feel bound to accept recommendations and expert opinions when we find from a study of the record that the record supports different conclusions. Moreover, the testimony of many of the parties was not based on field testing conducted by them or upon an analysis of field testing made by others but were simply recommendations and expert

opinions of a general nature. In weighing these recommendations and expert opinions we cannot overlook the fact that many of these same parties offered recommendations and expert opinions of the same kind as the basis of their advocacy in the 1946-1947 hearing of the simultaneous system—a system which never survived field testing.

D. *The CBS System*

140. This leaves for consideration the CBS system. In the Commission's opinion, the CBS system produces a color picture that is most satisfactory from the point of view of texture, color fidelity and contrast. The several demonstrations on the record included a wide variety of subject matter both in the studio and out of doors and the picture which resulted was in each case entirely suitable for home viewing purposes.

141. Receivers and station equipment are simple to handle. They have been subjected to use in widely diversified circumstances and no difficulty has been encountered. The receivers are simple and when produced on a mass marketing basis, should be within the economic reach of the great mass of purchasing public.

[fol. 164] 142. The susceptibility to flicker in the CBS system is greater than in the present monochrome system but in the Commission's view the brightnesses that have been achieved on disc receivers are adequate for home use and the evidence concerning long persistence phosphors shows that there is a specific method available for increasing brightness on non-disc receivers with no objectionable flicker. The CBS system is subject to color fringing or color breakup under certain circumstances. This is not a serious obstacle for two reasons. In the first place, many viewers after awhile tend not to see these defects. This is evident from a comparison of the little amount of comment on this subject in this hearing, compared to the 1946-1947 hearing. In the second place, these effects occur rather infrequently and many of them can be minimized by programming techniques. When they do occur, they are no more annoying to the viewer than stroboscopic effects in motion pictures.

143. The CBS system has less geometric resolution than the present monochrome system but the addition of color more than outweighs the loss in geometric resolution so far

as apparent definition is concerned. Of course, owners of receivers which have adapters but which are not built for color will receive only a black and white picture from CBS color transmissions—a picture which will not have color to compensate for the loss in resolution. However, this is a matter of choice for the viewer; he can have color if he so desires. Moreover, the black and white picture he receives from CBS color transmissions is still an acceptable picture; the degradation is of the order involved when black and white pictures are transmitted over the coaxial cable. There appears to be no alternative to some degradation in the quality of the black and white picture from color transmissions since even the so-called compatible systems suffer from the same failing.

[fol. 165] 144. At the present time, the CBS system is, as a practical matter, limited to projection receivers or direct-view tubes of no greater size than $12\frac{1}{2}$ inches (which can be magnified to 16 inches). Projection receivers have not had widespread public acceptability and the trend in direct-view receivers is to tube sizes larger than $12\frac{1}{2}$ inches. The tri-color tube demonstrated by RCA is not limited to $12\frac{1}{2}$ inches and RCA witnesses as well as other witnesses agreed that the tri-color tube could be utilized on the field sequential system. The Commission has no doubt that this is so, if the tube is successfully developed. However, at the one demonstration on the record when such a tube was shown—the RCA demonstration of April 6, 1950—the pictures were not in correct registration. It was not possible to determine whether the registration difficulties were at the camera or in the tri-color tube, or both. Since accurate registration has proved exceedingly difficult to achieve at the receiver as well as at the camera in the RCA system, the Commission is unable to conclude on the basis of this record that a successful tri-color tube has been devised with correct registration built into it. Moreover, the RCA tube as demonstrated had inadequate resolution, insufficient brightness, and a serious moire pattern in it. Finally, we are not certain that the color fidelity of a tri-color tube is of sufficiently high quality for a broadcast service.

145. Since there was no demonstration on the record of a direct view tri-color tube on the CBS system, the record does not contain a definitive answer as to whether direct-view tubes larger than $12\frac{1}{2}$ inches are possible with the CBS system. Thus two difficult courses of action are open

to the Commission. The first course of action is to reopen the record and to have a demonstration on the record wherein a tri-color tube or other technique for displaying large size direct-view pictures could be tried out on the CBS system. The second course of action is to adopt a final decision now promulgating color standards on the basis of the CBS system with the confidence that since the radio industry has succeeded in creating much larger tube sizes than those demonstrated in 1941 when standards for black and white television were adopted, they would succeed in building apparatus that would eliminate the present limitation in the CBS system as to size of direct view tube.

146. The advantage of the first course of action is that the Commission would not be compelled to speculate as to an important basis for its decision but would have a definitive answer on the basis of which to act. The disadvantage is that it would postpone a final decision and hence would aggravate the compatibility problem. The time already devoted to this hearing has magnified the problem. The advantage of the second course of action is that — would bring a speedy conclusion to the matters in issue and would furnish to manufacturers a real incentive to build a successful tri-color tube as soon as possible. A real competitive advantage would accrue to the company that succeeded in bringing out such a tube. The disadvantage is that the Commission's determination on an important part of its decision would be based on speculation and hope rather than on demonstrations.

[fol. 166] 147. Three other matters present the Commission with the same difficult choice between the two courses of action referred to above. Two developments were demonstrated in this hearing which hold real promise for increasing definition both in color and black and white pictures. One is horizontal interlace and the second is the efficacy of long persistence phosphors in reducing flicker, thus providing the means for decreasing the field rate and increasing the number of lines in the picture. Both of these techniques require further testing and, if successful, may make desirable additional changes in the field and line repetition rate.

148. The third matter we refer to is the possibility of new color systems and improvements in existing color systems which have been informally called to our attention since the hearings closed. Of course, these are not matters

of record and cannot be relied on in reaching a decision unless the record is reopened. In considering these developments the Commission is aware that the institution of these proceedings stimulated great activity in the color field and that since fundamental research cannot be performed on schedule, it is possible that much of the fruit of this research is only now beginning to emerge. On the other hand, the Commission cannot overlook the obvious fact that one of the easiest methods of defeating an incompatible system is to keep on devising new compatible systems in the hope that each new one will mean a lengthy hearing so that eventually the mere passage of time overpowers the incompatible system by the sheer weight of receivers in the hands of the public.

149. The answer as to which course of action to choose depends on whether a method exists for preventing the aggravation of the compatibility situation if a final decision is postponed. If there is no method to accomplish this, the Commission believes that a final decision should not be delayed and that the CBS color system should now be adopted. This would be consonant with our action in launching black and white television in 1941. On the basis of this record, the CBS color system is at least as fully developed as was the black and white system in 1941. However, if there is a method whereby aggravation of the compatibility problem can be avoided, we would feel more confident in postponing a decision so that a definitive resolution could be had of the matters set forth in the preceding paragraphs.

150. The answer to this question rests with the radio manufacturing industry. Existing television receivers are built to operate on transmission standards that have a horizontal synchronizing rate of 15,750 and a vertical synchronizing rate of 60. As a practical matter, the oscillators on receivers that accomplish the synchronization are built so that this response is broader than the specific figures set forth above. For example, if the horizontal synchronizing rate were 15,000 or 16,000, the receiver could accommodate itself to the change; there are controls on the front or back of the receiver that can be adjusted to operate on any figure within the assumed bracket 15,000 to 16,000. The same is true for the vertical oscillator. It is obvious that if the bracket within which the receiver could operate were as high as 29,160 for the horizontal oscillator and 144 for the

[fol. 167] vertical oscillator,³² it would be capable of receiving CBS color transmissions in black and white simply by the adjustment of controls already on the receiver. Moreover, such a receiver would be capable of handling the different synchronizing rates that might be later adopted by the Commission for modification of the existing black and white, or CBS field sequential color, or both, as a result of further tests with horizontal interlace and long persistence phosphors.

151. In order to accomplish this purpose, the Commission simultaneously with the release of this Report is issuing a Notice of Proposed Rule Making providing for bracket standards in the present monochrome system. These bracket standards provide for a television composite video signal of substantially the type and proportion now employed in monochrome, but with the number of lines variable from 15,000 to 32,000 per second, and number of fields ranging from 50 to 150 per second.³³ Receivers built to incorporate such bracket standards would be equipped with a manual or automatic switch to select instantaneously between two sets of standards falling within the above ranges, one of which will be the present monochrome standards, and the other the CBS proposed standards. The receiver would produce pictures of equivalent size, geometrical linearity and brightness on each of the two positions of the switch. Interested persons are given until September 29, 1950 to submit comments. In addition, manufacturers are requested to submit a statement as to whether if the bracket standards are adopted they would, commencing with the effective date of the order adopting the bracket standards as final—30 days after publication of the order in the Federal Register—build all their television receivers so as to be capable of operating within the above brackets. If, on the basis of the comments submitted, the Commission is able to adopt the bracket standards as final without a hearing and if the Commission receives assurances from a sufficient number of manufacturers to insure that such bracket

³² See Paragraph 42.

³³ The Notice provides that if the brackets are adopted, television broadcasters will continue, until further order of the Commission, to broadcast in accordance with present standards—15,750 lines per second and 60 fields per second.

standards will be incorporated in the great majority of television receivers, then we will be in a position to postpone a decision in this proceeding since we will have the time to explore more fully the matters set forth above, confident in the knowledge that adequate provision has been made to prevent aggravation of the compatibility question. If the bracket standards cannot be made final without a hearing or if assurances are not received from a sufficient number of manufacturers concerning their plans for incorporating bracket standards in their receivers, the Commission will not feel free to postpone a decision, for every day that passes would aggravate the compatibility problem. In that event, a final decision would be issued adopting the CBS color standards.

[fol. 168] 152. One of the proponents of a color system in these proceedings is a substantial manufacturer of television receivers. One of the companies which has informally advised the Commission that it has developed a new color system is also a substantial manufacturer of television receivers. Two other parties in this proceeding are in the same category. Finally, the Radio and Television Manufacturers Association, a party in these proceedings, is a trade association whose membership comprehends a very large part of the television manufacturing capacity in this country. Within this group lies the answer as to whether the status quo on compatibility will be maintained if the Commission postpones the issuance of a final decision at this time. The Commission proposes to afford this group an opportunity to indicate to the Commission this answer by means of the procedure set forth in the previous paragraph.

153. If, pursuant to the procedure set forth in Paragraph 151, bracket standards are adopted as final and a decision as to the color phase of these proceedings is postponed, the Commission will issue a second Notice of Proposed Rule Making proposing that color standards be adopted on the basis of the CBS field sequential system. The same bracket standards set forth for black and white television in the previous paragraph would also be proposed for color television. In addition, interested persons would be invited to conduct field tests with respect to horizontal interlace for use in both black and white and color television so that specific proposals based upon such field testing could be

presented to the Commission for its consideration. Also, provision would be made for any person to propose a color system different from the field sequential color system proposed in the Notice by complying with the procedure set forth in Paragraph 154.

154. A special procedure would be established with respect to submission of comments addressed to the second Notice. Any person desiring to submit comments in favor of or in opposition to the Notice, or who desired to submit proposed amendments could do so by January 5, 1951. Oppositions or replies could be filed by January 22, 1951. If any person desired to propose a color system different from the field sequential color system described in the Notice, he would be required to deliver representative receiver apparatus to the Commission's laboratory at Laurel, Maryland, by December 5, 1950, and by that same date he would be required to have a signal on the air in Washington, D. C., for the purpose of demonstrating his system. He would also be required to conduct a series of demonstrations during the period from December 5, 1950 to January 5, 1951 to which the Commission would be invited. No color system would be considered eligible for any consideration by the Commission unless all of the above requirements were strictly complied with and unless the tests conducted during the period from December 5, 1950 to January 5, 1951 showed to the Commission's satisfaction that, in its judgment, the system had a reasonable prospect of satisfying all of the criteria for a color television system set forth in Paragraph 122.

[fols. 169-170] 155. It is apparent that the procedure described in Paragraphs 151-154 could necessitate a reopening of the record. This would be done if CBS desired to demonstrate its system with a direct view tri-color tube or other technique of displaying large size direct view pictures. In that event the Commission would be prepared to give CBS every assistance possible in securing the use of tubes or other equipment. The Commission would not expect that at the demonstration CBS should show a commercial type of equipment or equipment that was fully developed. What would be expected would be a detailed description of the equipment, an opportunity for the Commission's laboratory to examine such equipment, and a demonstration that was sufficiently successful so as to form the basis for a reason-

able judgment that it would be possible to have color pictures of adequate color fidelity and resolution with no artificial limitation on the size of direct view tubes.

156. A hearing could also be required if an appropriate proposal were made concerning horizontal interlace or if a color system were proposed which fully meets the conditions set forth in the previous paragraphs. If the record is reopened for any one or more of the above purposes, the Commission's order will specifically prescribe the issues as to which further evidence will be taken and no evidence will be received concerning any other matter.

157. Simultaneously with the issuance of this Report, the Commission is also issuing a Notice of Proposed Rule Making providing for bracket standards in the present monochrome system and a notice setting the date of October 2, 1950 for commencement of hearing with respect to the general issues in these proceedings.

Federal Communications Commission. T. J. Slowie,
Secretary.

Adopted: September 1, 1950.

Released: September 1, 1950.

* Commissioners Hyde and Hennock writing separate views and Commissioner Jones dissenting in part.